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硕 士 学 位 论 文

两轮机器人自平衡和运动控制设计与实现

The System Design and Implementation of a Two-Wheeled Self-Balancing and Motion Control

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摘　要

随着社会的发展和科技的进步，移动机器人的应用领域愈发广泛，机器人面临的工作环境和任务需求也变得复杂多样，人们对它的要求和期待也越来越高。两轮自平衡机器人以其结构简单、运动灵活、占地空间小等优点受到了人们的重视，成为移动机器人研究领域的一个重要分支。

本文设计了一台重心位于轮轴下方的非载人两轮自平衡机器人基础运动平台。采用两轮同轴独立驱动，在运动过程中能较好地保持平衡。同时，在该运动平台上，设计实现具有一定载荷能力的稳定平台，用来搭载稳定性要求更高的设备。

本文的主要工作如下：

首先，以两轮机器人系统为研究对象，采用牛顿力学法建立系统动力学模型，将模型进行线性化处理，同时实现解耦，并对解耦得到的两个子系统进行可控、可观性分析。

其次，对平衡控制和速度控制进行分析，设计相应控制器，实现了系统运动与平衡控制。平衡控制采用模糊-PD控制，速度控制采用前馈-反馈复合控制，转弯采用对左右轮进行差速控制。仿真和物理实验表明，所设计的控制器能够取得良好的控制效果。

然后，采用了Kalman滤波算法对陀螺仪和加速度计的数据进行融合，准确获取两轮机器人平台倾角；针对车体倾角变化所引起的测量干扰，进行了有效补偿。设置的对照试验表明了补偿效果良好。

最后，完成了两轮机器人硬件、软件设计与实现，并在物理样机上进行了试验，试验结果表明了系统设计方法、控制及补偿算法的有效性。

关键词：两轮机器人；模糊-PID控制；前馈-反馈控制；姿态检测

Abstract

With the development of the society and the progress of science and technology, the mobile robots have been in various field, but the working environment and mission requirements also become complicated, which determines the classification of robots has been increasingly refined to meet different needs. The requirements and expectations of the people on the robots are also getting higher and higher. The two-wheeled self-balancing mobile robot have become an important branch in the area of robotics because of the advantages of simple structure, flexible movement, smaller size and etc.

In this paper, we design and implemented an unmanned two-wheeled self-balancing mobile motion platform which its center of gravity is below the axle. This robot has two independent driving wheels on the same axle which support and move the robot itself; it can maintain a good balance while moving. Meanwhile, a stable platform which has load ability is designed for greater stability requirements mounted equipment.

Thesis mainly finished the following work:

First of all, with two-wheeled mobile robot as the research object of the system, using the Newton mechanics method to establish the dynamics, then linearize the dynamics and decouple it into two subsystems, to analyze whether the decoupled system are observable, controllable or not.

In addition, we propose an algorithm for the two-wheeled robot by analyze the balance control and speed control. Using Fuzzy-PD controller to achieve self-balancing and yaw control. Feedforward-feedback controller is adopted in speed control to achieve fast response. Control the left and right wheels respectively in differential speed, complete turning purposes. In the simulation and physical experiments show that the designed controller can achieve good control effect.

Then, using the Kalman filter algorithm for gyro and accelerometer data fusion, to

accurately obtain angle information; we use measuring compensation for measuring interference, and set up the control test to verify its validity.
Finally, completed the design of hardware and software of two-wheeled mobile robot, The experiment was conducted on the physical prototype, the test results show the effectiveness of the design method, system control and compensation algorithm.

Keywords: Two-Wheeled Mobile Robot; Fuzzy-PD Control; Feedforward-Feedback Control; Attitude Detection

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